Proton Irradiation Test Report for the LTC6400-20 Differential ADC Driver

Test Date: Aug 4th – Aug 6th, 2009

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I. Introduction

The purpose of this study is to examine the proton irradiation effects, including angular effects, on the LTC6400-20 differential amplifier manufactured by Linear Technology.

II. Device Description

The LTC6400-20 is a high-speed differential amplifier, based on SiGe technology, designed to drive 12-, 14-, and 16-bit ADCs. The device features a fixed gain of 10 V/V (20 dB), and a -3dB bandwidth up to 1.8 GHz. The test/part information is listed in Table 1. The device specifications are listed in Table 2.

Table 1. Test and part information

Generic Part Number	LTC6400-20
Full Part Number	746 LCCS N112
Manufacturer	Linear Technology
Lot Date Code (LDC)	746
Quantity tested	1
Part Function	Differential amplifier
Part Technology	Silicon-Germanium
Package Style	16-lead QFN
Test Equipment	Power supply, RF generator, high-speed oscilloscope
Test Engineer	Anthony Phan

Table 2. Device specifications

Parameter	Test Conditions	Min	Typ	Max	Unit
Gain*	V_{IN} = ±100 mV Differential	19.4	20	20.6	dB
Supply Voltage (V_S)		2.85	3	3.5	V
Supply Current (I_S)	$\overline{\text{ENABLE}}$ = 0.8V	75	90	105	mA
Shutdown Supply Current (I_{SHDN})	$\overline{\text{ENABLE}}$ = 2.4V		1	3	mA

* The actual gain measured at the output of the demo board will be ~14 dB.

III. Test Facility

Facility: Indiana University Cyclotron Test Facility (IUCF)
Beam Energy: 198 MeV/amu

Flux: 5×10^8 to 3×10^9 particles/cm^2/s
Fluence: 1×10^{11} to 1×10^{12} particles/cm^2

IV. Test Method

Figure 1 shows the test circuit designed for single-ended input operation. The application circuit uses input and output transformers for single-ended-to-differential conversion and impedance transformation. The -3 dB bandwidth is reduced from 1.8 GHz to 1.3 GHz as a result of the transformers. A block diagram schematic of the test setup is shown in Figure 2. As illustrated in the block diagram, a computer controls the device operating frequency and signal levels. A LabVIEW program also monitors the output waveform. Figure 3 shows the delidded part on the test circuit board.

The irradiation was performed at normal incidence, 60^o and 90^o incident angles. We note that for 90^o incidence, the part was rotated along both its x and y axis, so that the cables are coming out from the top and bottom.

A high-speed digital oscilloscope was connected to the output of the board to capture any single-event-transient (SET). The oscilloscope and RF generator were placed outside of the irradiation chamber to avoid being damaged by the high energy radiation environment. Therefore several Sub-Multi-Assembly (SMA) cables were joined together for both the input and output connections. The cable lengths for both input and output were approximately 60 feet. The length of the cables limited the frequency range and slightly degraded the gain.

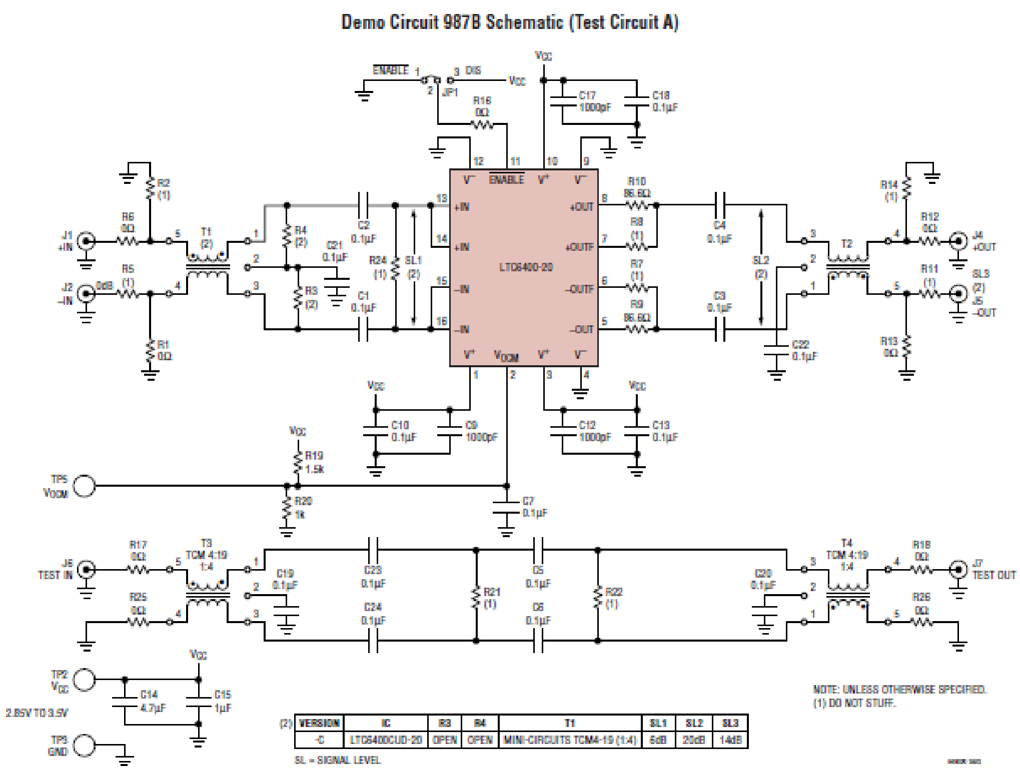

Figure 1. Application circuit configuration.

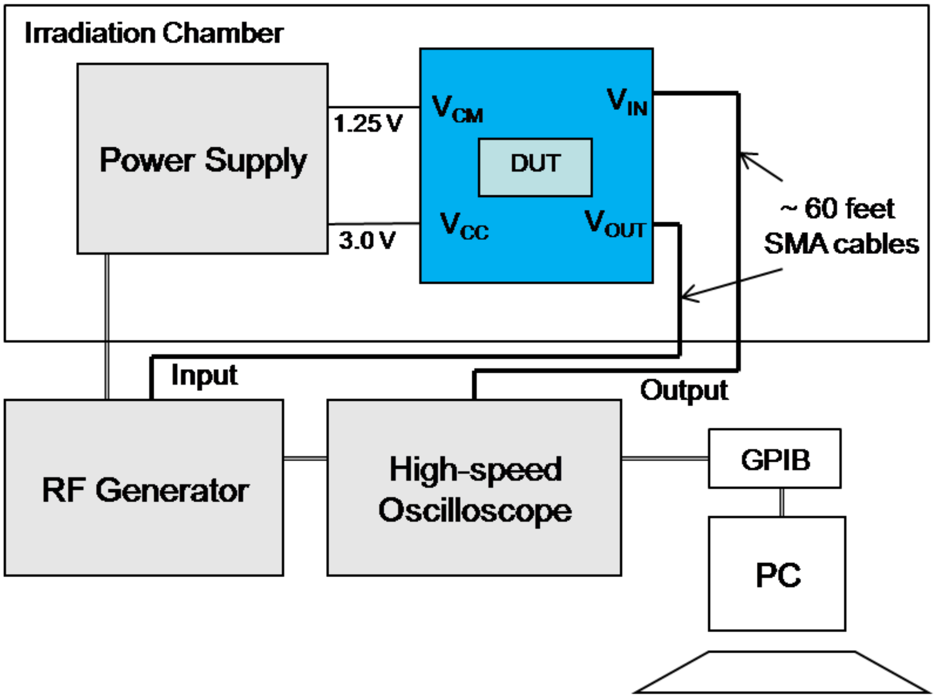

Figure 2. Test setup block diagram.

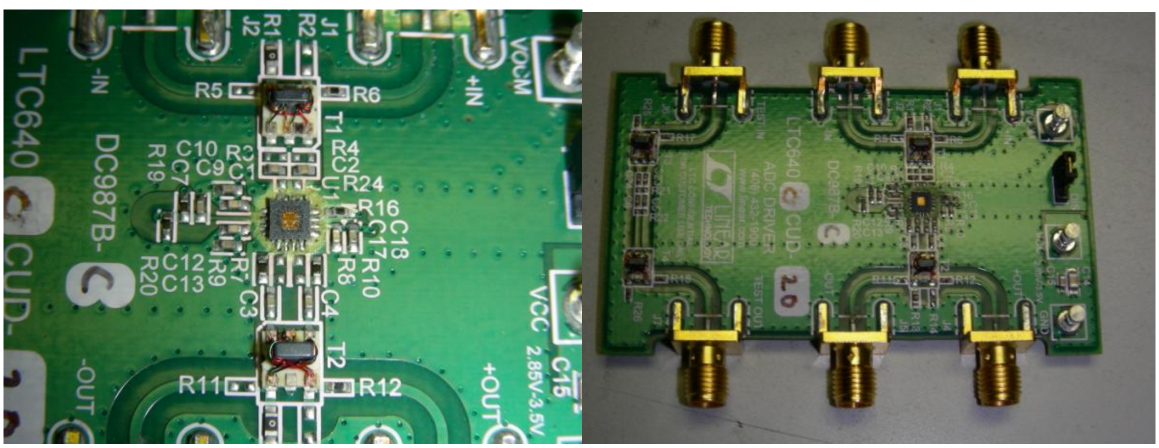

Figure 3. Photograph of a delidded part and the test board.

Test Conditions

Test temperature:	Ambient temperature (25°C)
Operating frequency:	10, 100, and 200 MHz
Supply voltage:	V_{CC} = 3 V, V_{CM} = 1.25 V
Input Voltage:	140 mV_{pp}, sine wave
Parameter:	(1) Single event transients, with trigger set at 2.7 ns and 2.3 ns
	(2) Supply, input and common mode currents
	(3) Single event latchups were also monitored
Data format:	LabVIEW waveform, processed to text file

Beam hours: **~2**

V. Results

Errors were characterized in the form of single event transients. No transients were observed at an initial fluence of 1×10^{11} particles/cm^2, with the device operating at a frequency of 200 MHz. The particle fluence was increased to 1×10^{12} particles/cm^2 for the rest of the experiment. Three transients were observed with device frequency of 200 MHz, for normal incident irradiation. The resulting error cross section was 3×10^{-12} cm^2. Next the device was rotated to an incident angle of 60^o. Eight transients were observed with an error cross section of 8×10^{-12} cm^2. The device was then irradiated at an incident angle of 90^o, which also resulted in 8 transients and an error cross section of 8×10^{-12} cm^2. On the next run the device was rotated back to normal incidence. The irradiation produced 15 transients with an error cross section of 1.5×10^{-11} cm^2. Finally the device was irradiated at normal incidence with device frequency of 10 MHz, producing no observable transients.

The irradiations at incident angles of 60^o and 90^o produced higher error cross sections than the initial normal incident irradiation. However the results are unlikely due to angular effects. Under the same experimental conditions, the part showed a larger error cross section from a later run relative to an earlier run both at normal incident irradiations. This suggests that the increase in the error rate is due to accumulated TID and/or displacement damage instead of angular effects. Figure 4 shows the SET error cross section vs. accumulated dose for different incident angle irradiations.

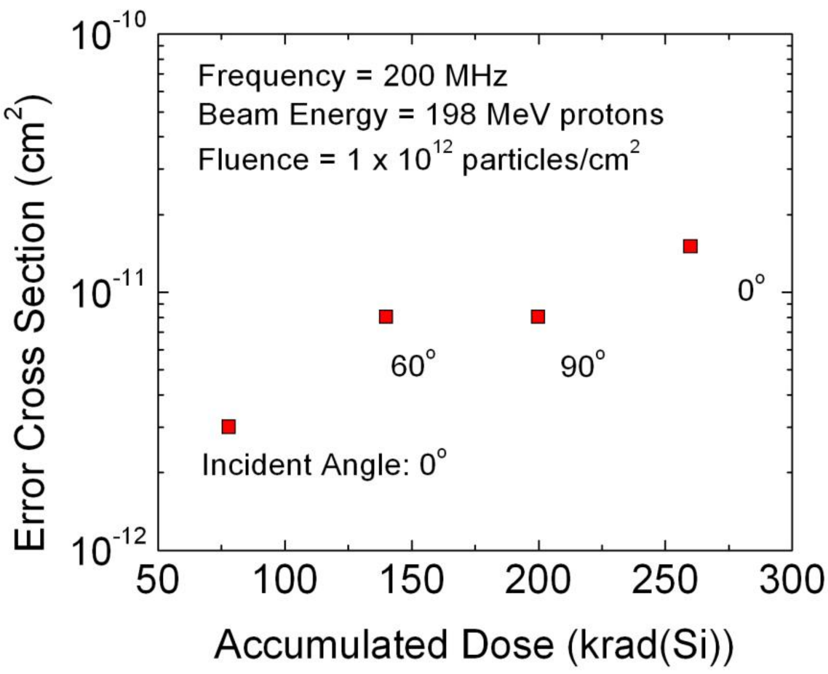

Figure 4. SET cross section vs. accumulated dose for the LTC6400 operating at 200 MHz, irradiated with 198 MeV protons to a fluence of 1×10^{12} particles/cm^2.

Additionally the SET characteristics are similar for the different incident angles. The SETs are voltage spikes that affect 1 cycle of the sinewave output signal for each event.

Figures 5 and 6 show the typical transients. The SET characteristics are also similar to those from heavy-ion irradiations. Furthermore no SET was observed at 10 MHz and a fluence of 1×10^{12} particles/cm^2. This indicates that a higher SET error rate at a higher frequency. The behavior is also consistent with the frequency dependence observed from heavy-ion irradiation.

The supply currents remained unchanged throughout the irradiation. No latchup or other destructive events were observed.

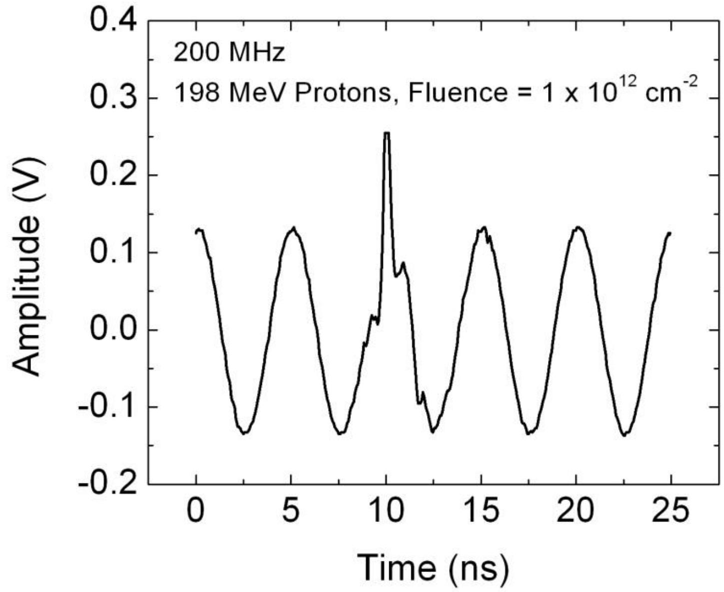

Figure 5. SET characteristics for the LTC6400 operating at 200 MHz from 198 MeV proton irradiation to a fluence of 1×10^{12} particles/cm^2.

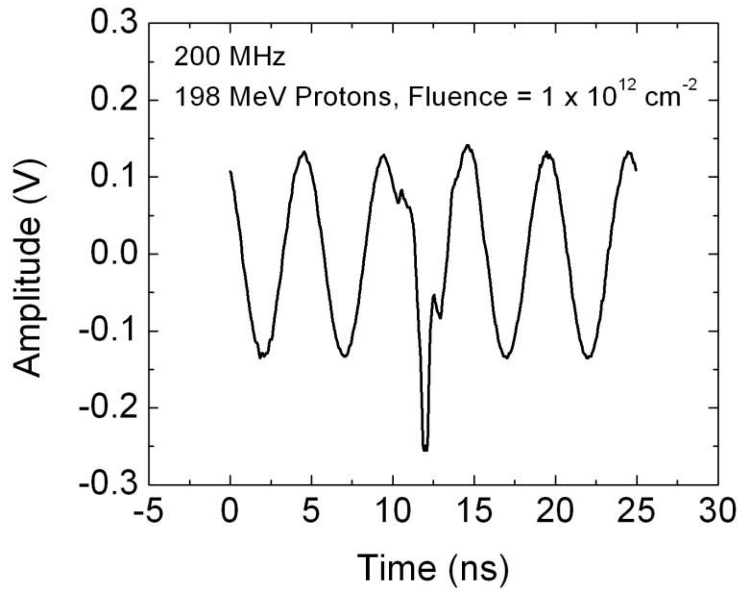

Figure 6. SET characteristics for the LTC6400 operating at 200 MHz from 198 MeV proton irradiation to a fluence of 1×10^{12} particles/cm^2.

VI. Conclusions

The results showed that the LTC6400 differential output amplifier is susceptible to SETs from high energy proton irradiation. However the SET error rate is extremely low. The irradiation produced a maximum SET cross section of 1.5×10^{-11} cm^2 for a fluence of 1×10^{12} particles/cm^2, with the device operating at 200 MHz. The results also showed that the device is relatively insensitive to angular effects. Accumulated TID and/or displacement damage likely increased the SET error cross sections. The transients are voltage spikes that may affect 1 data bit for each event, for 200 MHz operation. No SETs were observed at 10 MHz.

VII. Appendix

LTC6400-20, Vcc=3V and Vcm=1.25V

Run	Frequency (MHz)	Gain (V/V)	Incident Angle (degrees)	Beam Energy (MeV)	Avg Flux (#/(cm^2·s))	Fluence (#/cm^{-2})	TID (krad)	Errors	Total σ (cm^2)
28	10	5.0	0	198	5.90E+07	1.00E+10	0.6	0	0
29	10	5.0	0	198	5.60E+08	1.00E+11	6.59	0	0
30	100	3.5	0	198	5.70E+08	1.00E+11	12.58	0	0
31	200	3.0	0	198	5.20E+08	1.00E+11	18.57	0	0
32	200	3.0	0	198	2.81E+09	1.00E+12	78.37	3	3.00E-12
33	200	3.0	60	198	2.98E+09	1.00E+12	138.17	8	8.00E-12
34	200	3.0	90	198	2.62E+09	1.00E+12	197.97	8	8.00E-12
35	200	3.0	0	198	2.91E+09	1.00E+12	257.77	15	1.50E-11
36	10	5.0	0	198	2.83E+09	1.00E+12	317.57	0	0